Research on Optimization of Production Line of Type a Product

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Abstract. In this paper, industrial engineering knowledge is applied to the improvement of a product production line of a company to solve the problems such as low production balance rate, high smoothness index, unreasonable production line layout and insufficient on-site management. Through field data collection, the process program analysis and process status analysis of the production line are carried out. The collected data are simulated and analyzed by Flexsim. The simulation output results are highly consistent with the actual situation, which proves the authenticity of the data. 5W1H method is used to dissect the root of the problem, the ECRs principle is used to improve the tooling of the production line, process merging, and personnel adjustment to level the production line Finally, Flexsim simulation technology is used to verify the feasibility of the scheme, and the benefits of the production line are quantitatively evaluated through mathematical modeling. The production balance rate is increased by 25%.

Keywords: Production line balance rate · ECRS principle · Flexsim simulation · Production line layout

1 Production Status and Problem Analysis

Semiconductor diode lasers are widely used in laser communication, optical storage and radar. A company is a Taiwan funded enterprise that produces laser modules. Its product a is the prototype of module series products. The production line and workshop of this product have problems such as production line shutdown and overproduction. In order to find out the influencing factors, it is necessary to conduct action research and time measurement on the production line of the product [1]. Under the condition of not introducing new manufacturing equipment, lean production is used to improve the production efficiency by improving the smelting tools, adjusting the personnel quota of the production line process and optimizing the layout of the production line.

Product Characteristics

The company mainly produces laser module products. As shown in Fig. 1, it is a basic module product a. the research, analysis and improvement of this product production line can also be applied to other products with similar structure. Due to the small volume, anti-static and large amplitude vibration, the products are transported in batches according

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to the pallet load shown in Fig. 2 during the production process. The time interval of material transfer is long, so it is not suitable for conveyor belt transportation. The process flow chart is shown in Fig. 3.

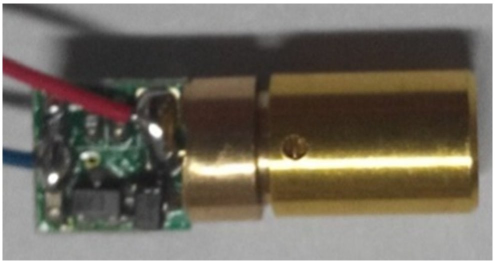


Fig. 1. Product drawing of laser module

Fig. 2. Anti-static material rotary table

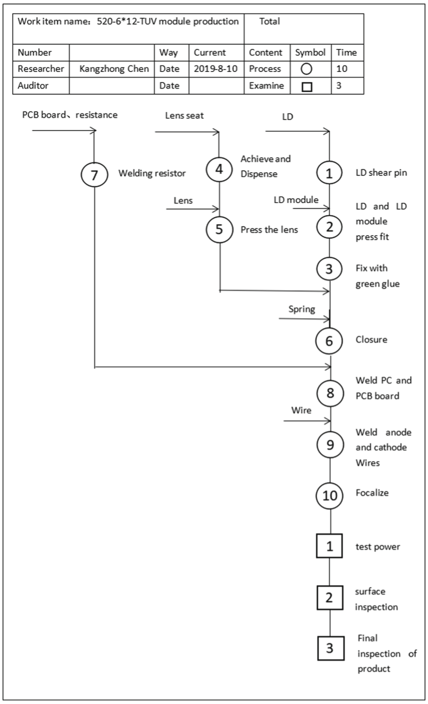


Fig. 3. Process flow chart

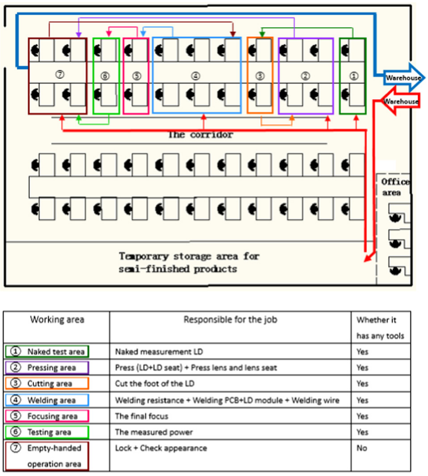


Fig. 4. Workshop layout and handling route map

Current Situation of Production Workshop

There are 4 production lines in the workshop, each with 11 posts. The layout of the workshop and the transportation route are shown in Fig. 4.

As can be seen from the figure, the process connection before and after the production line layout is not close, there is no information exchange between the processes, the material situation can not be transmitted in time, moving and transporting materials causes the transportation waste, and the logistics path is cross circuitous and chaotic, which often leads to the waste of waiting due to the untimely supply of materials, the staff's enthusiasm is reduced and the efficiency is reduced. The workload and personnel ratio of each process post is unreasonable, which aggravates the waste of waiting.

Equilibrium Rate Analysis

The stopwatch method is used to measure the operation of each process of the production line, and to evaluate the standard working hours [2]. Combined with the company's existing information, the relevant technical requirements of such products are inquired about, and the situation of the fixed number of personnel is integrated, and the flow chart as shown in Fig. 5 is made (100 products are a batch). As shown in Fig. 6, the standard working hour diagram of the station [3].

According to the above values, using formula (1) to calculate the balance rate (RATE is the production balance rate; $\sum_{i=1}^{n} x_i$ is the sum of the process time; $nx_{\max}$ represents the number of work stations * bottleneck process time), the balance rate is calculated to be 52%, which is relatively low, the task allocation of each station is unreasonable, and the characteristics of bottleneck and redundant stations are more prominent [4].

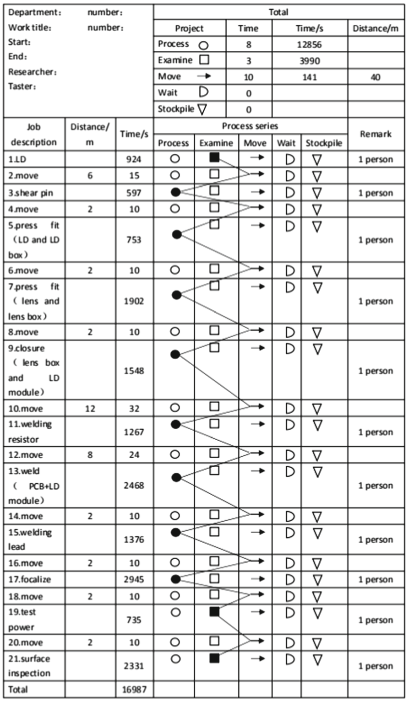


Fig. 5. Flow chart

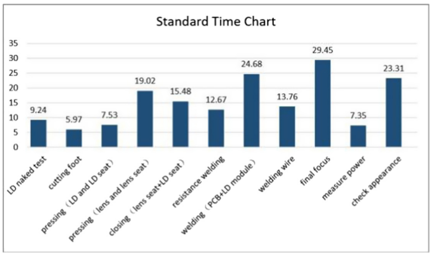


Fig. 6. Standard time chart

$$RATE = \frac{\sum_{i=1}^{n} X_I}{nx_{max}} = \frac{168.46}{323.98} = 0.52 \quad (1)$$

The smoothness index of the production line is analyzed. The smoothness index is an index to measure the fluctuation of working hours by calculating the relationship between the working hours of different positions on the production line. The specific formula is as follows:

$$SI = \sqrt{\frac{\sum_{i=1}^{n}(CT - Ti)^2}{n}} = \sqrt{\frac{2820}{11}} = 16.0 \tag{2}$$

SI is the smoothness index; *Ti* is the standard working hours of each process; *CT* is the bottleneck process time; *n* is the number of operators. The larger the *SI* value is, the more dispersed the working time distribution of each station is; the smaller the *SI* value is, the more centralized the operation time distribution of each station is. The *SI* of the production line is 16.01, which indicates that the working time of each station is uneven [5].

Among them, the focalize is the bottleneck process, and the LD, shear pin, press fit (LD and LD box) and test power are redundant positions. In conclusion, a series of production line problems are obtained as shown in Fig. 7.

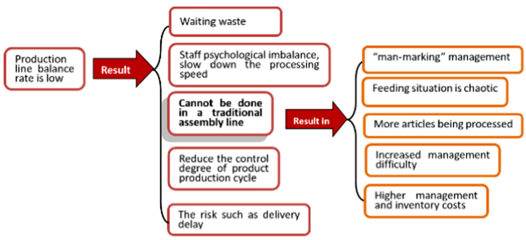


Fig. 7. Production line problem diagram

2 Analysis of Production Line Position Problems

2.1 Redundant Station Analysis

Through the analysis of the process of shear pin, press fit (LD and LD box) and press fit (lens and lens box), it is found that there are many waste of actions in the process. The mould has no positioning function and needs manual positioning by visual inspection, and it is easy to crush the LD pin and cause product scrapping. The tools used in the appearance inspection process are only blades and alcohol, and the power measurement process is the previous process. The difference between the standard working hours of the two processes is relatively large. After the appearance inspection and power measurement procedures are combined, the standard working hours of the two processes can be balanced by re staffing.

The bottleneck process is analyzed, and the final focusing is the bottleneck process. Field observation shows that the action time of focusing operation accounts for less in the whole process, and the main time-consuming step is the subjective manual identification time of light points, and the production line balance rate can be improved by increasing the personnel ratio [6].

2.2 Production Line Analysis Based on Flexsim

According to the original data of workshop layout, logistics line and production site management before optimization, the simulation parameters of the production line are set. After the parameters are input, the entities are connected logically. In order to facilitate the research and analysis, the model is simplified in three aspects on the basis of reflecting the actual production situation [7], as shown in Fig. 8.

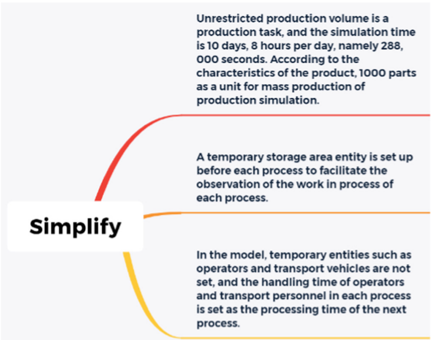
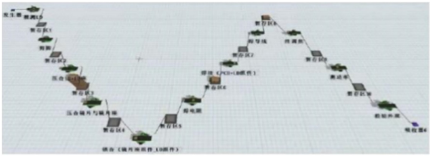


Fig. 8. Model simplified mind map



Object	Class	idle	empty	releasing	processing	setup	input	output
LD naked test	Processor	0.00%	0.00%	0.00%	99.78%	0.00%	312	311
Cutting foot	Processor	33.91%	0.00%	0.00%	66.09%	0.00%	311	311
Pressing (LD+LD seat)	Processor	17.87%	0.00%	0.00%	82.13%	0.00%	311	310
Pressing lens and lens seat	Processor	0.80%	0.00%	0.00%	98.92%	0.00%	150	149
Closing (lens module and LD module)	Processor	19.66%	0.00%	0.00%	80.06%	0.00%	149	148
Resistance welding	Processor	33.30%	0.00%	0.00%	66.30%	0.00%	148	147
Welding (PCB+LD module)	Processor	2.46%	0.00%	0.00%	96.91%	0.00%	113	112
Welding wire	Processor	45.95%	0.00%	0.00%	53.90%	0.00%	112	112
Final focus	Processor	3.80%	0.00%	0.00%	95.42%	0.00%	94	93
Measure power	Processor	75.43%	0.00%	0.00%	24.06%	0.00%	93	93
Check appearance	Processor	24.70%	0.00%	0.00%	74.78%	0.00%	93	92
Absorber 6	Sink	0.00%	0.00%	0.00%	0.00%		92	0
Staging area 1	Queue	0.00%	99.78%	0.00%	0.00%		311	311
Staging area 2	Queue	0.00%	100.00 %	0.00%	0.00%		311	311
Staging area 3	Queue	0.00%	1.12%	98.82%	0.00%		310	150
Staging area 4	Queue	0.00%	99.72%	0.00%	0.00%		149	149
Staging area 5	Queue	0.00%	99.60%	0.00%	0.00%		148	148
Staging area 6	Queue	0.00%	3.91%	95.48%	0.00%		147	113
Staging area 7	Queue	0.00%	99.37%	0.00%	0.00%		112	112
Staging area 8	Queue	0.00%	6.58%	93.27%	0.00%		112	94
Staging area 9	Queue	0.00%	99.23%	0.00%	0.00%		93	93
Staging area 10	Queue	0.00%	99.49%	0.00%	0.00%		93	93
generator	Source	0.00%	0.00%	0.00%	0.00%		0	312

Fig. 9. Simulation output diagram

The simulation model is established based on the original process flow of product a. the simulation plan, 3D diagram and simulation status are analyzed. The simulation output is shown in Fig. 9.

In the idle column data, most of the time of cutting foot, welding resistance, welding wire and measuring power of the original process are idle waiting state, accounting for 33.91%, 33.30%, 45.95% and 75.43% of the total time respectively. In the empty column, the idle rate of temporary storage area 3 is 1.12%, that of temporary storage area 6 is 3.91%, and that of temporary storage area 8 is 6.58%. It indicates that there are different degrees of work in process from press fit (LD and LD box), press fit (lens and lens box), welding resistance welding (PCB and LD assembly), welding wire - Final focusing, among which the welding wire - Final focusing WIP is particularly serious, with a daily output of 92 units, It is consistent with the actual situation to prove the authenticity and validity of the data.

3 Product Production Improvement and Optimization Scheme

Through the above problem analysis, we use relevant tools and methods to optimize the workshop of product a according to certain principles. The specific optimization plan is shown in Fig. 10.

Fig. 10. Overall planning of production line optimization scheme

3.1 Optimization Ideas

According to the current situation of the production system, 5W1H question and answer method is used for analysis. After summarizing the questions, it is concluded that the existing waste phenomenon in the production system is mainly due to the unreasonable arrangement of each station in the production line and the low production balance rate of the production line, resulting in the production line waiting for waste and handling.

3.2 Improvement Principle

In order to improve this phenomenon, the ECRS principle (Eliminate/Combine /Rearrange/Simplify) is used to analyze the improvement of the production line. Combined with the field operation situation, the ECRS principle analysis is made. To improve the production line balance rate and production efficiency, reduce the number of work in process, reduce the management difficulty, and enhance the controllability of the production cycle.

3.3 Improvement Design of Production Line Layout

The layout of the origin line is linear, and the material handling mode is to move between the work stations to transfer materials, so there is a lot of waste. According to the products in this paper, the position layout and production line layout are improved as shown in Fig. 11.

Due to the characteristics of the product, there is a blank area at the end of the production line as shown in Fig. 12. The production line is changed from a straight line to a U type, so that the workers can directly reach out to transfer materials without personnel walking, thus reducing the handling. At the same time, the connection of various processes is enhanced to a certain extent, which is convenient for management and reduces the difficulty of management [8]. The improved flow chart is shown in Fig. 13. According to the formula (1), the production balance rate after improvement is 77%.

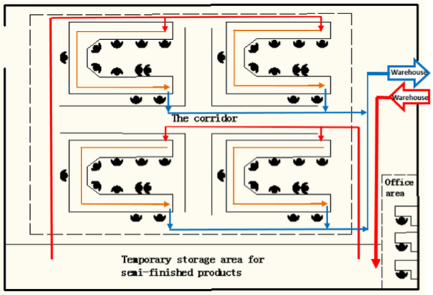


Fig. 11. Production line improvement chart

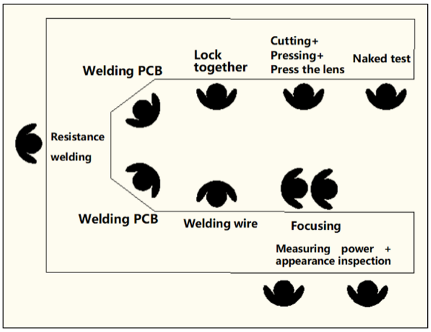


Fig. 12. Layout of each process

3.4 Analysis of Improved Production Line Based on Flexsim

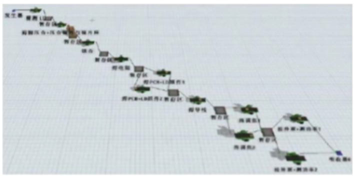
According to the optimized workshop layout, logistics line and production site management, the production line a is modeled and simulated. The simulation entity model and data output are shown in Fig. 14.

From the idle column data, the problem of too long idle time of equipment in the original process flow was solved. At the same time, the utilization rate of welding resistance and welding wire equipment was also improved. The effect is shown in Fig. 15.

In the empty column data, except for temporary storage area 2, the idle rate of other temporary storage areas is close to 100%, indicating that the problem of welding wire and final focusing WIP has been solved, and there is no backlog of work in process in other processes. The problem of long idle time of equipment in the original process flow is solved. At the same time, the utilization rate of welding resistance and welding wire equipment is also improved.

Department: number:			Total					
Work title: number:			Project	Time		Time/s		Distance/m
Start:			Process ○	6		6291		
End:			Examine □	2		2040		
Researcher:			Move →	0				
Taster:			Wait D	0				
			Stockpile ▽	0				
Job description	Distance /m	Time /s	Process series					Remark
			Process	Examine	Move	Wait	Stockpile	
1.LD		924	○	■	→	D	▽	1 person
2. shear pin and press fit（LD and LD box ）+press fit（lens and lens box）		597	●	□	→	D	▽	1 person
3. closure（lens box and LD module）		753	●	□	→	D	▽	1 person
4.welding resistor		1902	●	□	→	D	▽	1 person
5.weld（PCB+LD module）		1548	●	□	→	D	▽	2 person
6. welding lead		1267	●	□	→	D	▽	1 person
7. focalize		2468	●	□	→	D	▽	2 person
8.test power+surface inspection		1376	○	■	→	D	▽	2 person
Total		8331						

Fig. 13. Improved production flow chart



Object	Class	idle	empty	releasing	processing	setup	input	output
LD naked test	Processor	0.00%	0.00%	0.00%	99.78%	0.00%	312	311
Cutting foot pressing + pressing lens and lens seat	Processor	32.29%	0.00%	0.00%	67.49%	0.00%	311	310
Closing	Processor	0.54%	0.00%	0.00%	99.44%	0.00%	186	185
Resistance welding	Processor	19.03%	0.00%	0.00%	80.95%	0.00%	185	184
Welding PCB+LD module 1	Processor	21.36%	0.00%	0.00%	77.98%	0.00%	92	91
Welding PCB+LD module 2	Processor	21.90%	0.00%	0.00%	77.98%	0.00%	92	91
Welding wire	Processor	13.19%	0.00%	0.00%	86.48%	0.00%	182	181
Final focus 1	Processor	7.54%	0.00%	0.00%	92.06%	0.00%	91	90
Final focus 2	Processor	8.03%	0.00%	0.00%	91.04%	0.00%	90	89
Check appearance + power 1	Processor	30.58%	0.00%	0.00%	68.98%	0.00%	90	89
Check appearance + power 2	Processor	30.82%	0.00%	0.00%	68.98%	0.00%	89	89
Absorber 6	Sink	0.00%	0.00%	0.00%	0.00%		178	0
Staging area 1	Queue	0.00%	99.78%	0.00%	0.00%		311	311
Staging area 2	Queue	0.00%	0.97%	98.71%	0.00%		310	186
Staging area 3	Queue	0.00%	99.98%	0.00%	0.00%		185	185
Staging area 4	Queue	0.00%	99.88%	0.00%	0.00%		184	184
Staging area 5	Queue	0.00%	99.66%	0.00%	0.00%		182	182
Staging area 6	Queue	0.00%	99.60%	0.00%	0.00%		181	181
Staging area 7	Queue	0.00%	99.55%	0.00%	0.00%		179	179
Generator	Source	0.00%	0.00%	0.00%	0.00%		0	312

Fig. 14. Simulation output

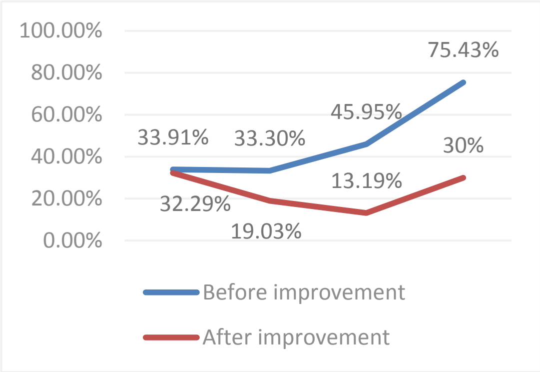


Fig. 15. Comparison chart of model improvement idle rate

4 Comparative Analysis of Balance Rate

According to the standard working hours before and after the improvement, a comparison chart of standard working hours as shown in Fig. 16.

Using the formula of balance rate (formula 1), the balance rate is 77% after improvement, which is increased from 52% to 77%.

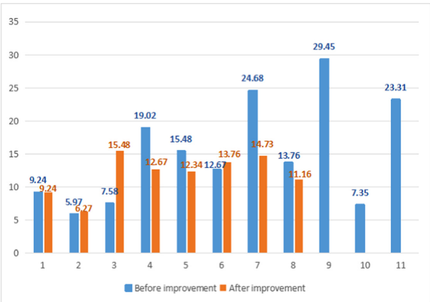


Fig. 16. Comparison chart of standard working hours

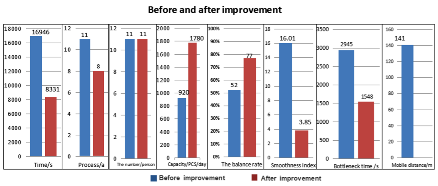


Fig. 17. Comparison of improvement effect of production line

Using the formula of smoothness index (formula 2), the *SI* is 3.85, and the smoothness index is significantly reduced, which indicates that the working hours of each process are closer to each other and the production load is close to equilibrium. The summary of all projects before and after optimization is shown in Fig. 17.

5 Conclusion

In this paper, the traditional IE combined with Flexsim simulation technology and mathematical modeling can solve the problems of low production balance rate, high smoothness index, unreasonable production line layout and insufficient field management. Flexsim simulation technology is used to analyze the collected data and verify the feasibility of the scheme. Through mathematical modeling and quantitative evaluation of the production line benefit, the scheme makes the production balance rate increase by 25%, the improvement model is suitable for the improvement of other similar product production lines of the company [9].

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